TRANSLATION

I, Yuko Mitsui, residing at 4-6-10, Higashikoigakubo, Kokubunji-shi, Tokyo, Japan, state:

that I know well both the Japanese and English languages,

that I translated, from Japanese into English, Japanese Patent Application No. 11-234767, filed on August 20, 1999, and

that the attached English translation is a true and accurate translation to the best of my knowledge and belief.

Dated: September 21, 2004

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PATENT OFFICE
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Date of Application: August 20, 1999

Application Number: Patent Application No. 11-234767

Applicant(s): The Furukawa Electric Co., Ltd.

This 25th day of May 2001

Commissioner,
Patent Office

Kozo OIKAWA (seal)

Certificate No.2001-3044263

[Name of Document]	PATENT APPLICATION
[Reference Number]	990337
[Filing Date]	August 20, 1999
[To]	Commissioner, Patent Office
[International Patent Classification]	G02B 6/16 G02B 6/22 H04B 10/00
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[Indication of Official Fee]	
[Prepayment Register Number]	005267
[Amount of Payment]	¥21,000.-
[List of Items Submitted]	
[Name of Item]	Specification 1
[Name of Item]	Drawing 1
[Name of Item]	Abstract 1

[Document] SPECIFICATION

[Title of the Invention] OPTICAL FIBER AND OPTICAL TRANSMISSION LINE

[What is claimed is:]

[Claim 1] An optical fiber which has a dispersion value at a set wavelength band in a 1.5 μm-wavelength band, of 14 to 24 ps/nm/km, and, an effective core area at a central wavelength of said set wavelength band is 95 μm^2 or more, and a bending loss at a bending diameter of 20 mm is 20 dB/m or less, and which operates in a single mode at said set wavelength band.

[Claim 2] An optical fiber which has a dispersion value at a set wavelength band in a 1.5 μm-wavelength band, of 6 to 14 ps/nm/km, and, an effective core area at a central wavelength of said set wavelength band is 70 μm^2 or more, and a bending loss at a bending diameter of 20 mm is 20 dB/m or less, and which operates in a single mode at said set wavelength band.

[Claim 3] An optical fiber according to any one of claims 1 or 2, wherein a dispersion slope (unit: $ps/nm^2/km$) at said set wavelength band is 0.08 or less in absolute value.

[Claim 4] An optical fiber according to any one of claims 1 to 3, wherein a transmission loss at a central wavelength in said set wavelength band is 0.25 dB/km or less, and a polarization mode dispersion value is 0.15 $ps/km^{1/2}$ or less.

[Claim 5] An optical fiber according to claim 4,

wherein a transmission loss at an entire region of the set wavelength band is 0.25 dB/km or less.

[Claim 6] An optical fiber according to any one of claims 1 to 5, which comprises a single layer core and clad, and has a refractive index profile of a single peaked structure, and which satisfies $0.2\% \leqq \Delta 1 \leqq 0.35\%$ where $\Delta 1$ is a relative refractive index difference of the core with reference to the refractive index of the clad.

[Claim 7] An optical fiber according to any one of claims 1 to 5, which comprises a single layer core and clad, and has a refractive index profile of a single peaked structure, and which satisfies $0.2\% \leqq \Delta 1 \leqq 0.6\%$ where $\Delta 1$ is a relative refractive index difference of the core with reference to the refractive index of the clad, and satisfies $1 \leqq \alpha \leqq 5$ where α is a value obtained when the refractive index profile is approximated with an α curve.

[Claim 8] An optical fiber according to any one of claims 1 to 5, which comprises a center core, a side core and a clad in order from an inner side, and has a refractive index profile of a two-layer core type, and which satisfies $0.2\% \leqq \Delta 1 \leqq 0.35\%$ and $-0.3\% \leqq \Delta 2 < 0$ where $\Delta 1$ is a relative refractive index difference of the center core, with reference to the refractive index of the clad, and $\Delta 2$ is a relative refractive index difference of the side core, with reference to the refractive index of the clad, and satisfies $0.3 \leqq a/b \leqq 0.7$ where a represents an outer diameter of the center core and b represents an outer

diameter of the side core.

[Claim 9] An optical fiber according to any one of claims 1 to 5, which comprises a center core, a side core and a clad in order from an inner side, and has a refractive index profile of a two-layer core type, and which satisfies $0.2\% \leqq \Delta 1 \leqq 0.7\%$ and $-0.3\% \leqq \Delta 2 \leqq -0.15\%$ where $\Delta 1$ is a relative refractive index difference of the center core, with reference to the refractive index of the clad, and $\Delta 2$ is a relative refractive index difference of the side core, with reference to the refractive index of the clad, and satisfies $0.3 \leqq a/b \leqq 0.7$ where a represents an outer diameter of the center core and b represents an outer diameter of the side core, and satisfies $1 \leqq \alpha \leqq 5$ where α is a value obtained when the refractive index distribution is approximated with an α curve.

[Claim 10] An optical fiber according to any one of claims 1 to 5, which comprises a center core, a side core and a clad in order from an inner side, and has a refractive index profile of a two-layer core type, and which satisfies $0.2\% \leqq \Delta 1 \leqq 0.35\%$ and $0 < \Delta 2 < \Delta 1$ where $\Delta 1$ is a relative refractive index difference of the center core, with reference to the refractive index of the clad, and $\Delta 2$ is a relative refractive index difference of the side core, with reference to the refractive index of the clad, and satisfies $0.3 \leqq a/b \leqq 0.7$ where a represents an outer diameter of the center core and b represents an outer diameter of the side core.

[Claim 11] An optical fiber according to any one of claims 1 to 5, which comprises a center core, a side core and a clad in order from an inner side, and has a refractive index profile of a two-layer core type, which satisfies $0.2\% \leqq \Delta 1 \leqq 0.7\%$, $0.15\% \leqq \Delta 2 \leqq 0.3\%$ and $\Delta 1 > \Delta 2$ where $\Delta 1$ is a relative refractive index difference of the center core, with reference to the refractive index of the clad, and $\Delta 2$ is a relative refractive index difference of the side core, with reference to the refractive index of the clad, and satisfies $0.3 \leqq a/b \leqq 0.7$ where a represents an outer diameter of the center core and b represents an outer diameter of the side core, and satisfies $1 \leqq \alpha \leqq 5$ where α is a value obtained when the refractive index profile is approximated with an α curve.

[Claim 12] An optical fiber according to any one of claims 1 to 5, which comprises a first core, a second core and a clad in order from an inner side, and has a refractive index profile of a two-layer core type, which satisfies $0.6\% \leqq \Delta 2 \leqq 1.0\%$ and $-1.2 \leqq \Delta 1/\Delta 2 \leqq -0.4$ where $\Delta 1$ is a relative refractive index difference of the first core, with reference to the refractive index of the clad, and where $\Delta 2$ is a relative refractive index difference of the second core, with reference to the refractive index of the clad, and satisfies $0.3 \leqq a/b \leqq 0.7$ where a represents an outer diameter of the first core and b represents an outer diameter of the second core.

[Claim 13] An optical fiber according to any one of

claims 1 to 5, which comprises a first core, a second core, a third core and a clad in order from an inner side, and has a refractive index profile of a three-layer core type, and which satisfies 0.6% $\leqq$ $\Delta 2$ $\leqq$ 1.0%, -1.2 $\leqq$ $\Delta 1/\Delta 2$ $\leqq$ -0.4 and 0.2 $\leqq$ $\Delta 3/\Delta 2$ $\leqq$ 0.6 where $\Delta 1$ is a relative refractive index difference of the first core, with reference to the refractive index of the clad, $\Delta 2$ is a relative refractive index difference of the second core, with reference to the refractive index of the clad, and $\Delta 3$ is a relative refractive index difference of the third core, with reference to the refractive index of the clad, and satisfies 0.3 $\leqq$ a/b $\leqq$ 0.7 and 0.2 $\leqq$ a/c $\leqq$ 0.5 where a represents an outer diameter of the first core, b represents an outer diameter of the first side core, and c represents an outer diameter of the second side core.

[Claim 14] An optical transmission line for transmitting an optical signal, wherein the optical fiber according to any one of claims 1 to 13, is arranged in the optical transmission line in its part.

[Detailed Description of the Invention]

[0001]

[Technical Field of the Invention]

The present invention relates to an optical fiber and an optical transmission line including the optical fiber, and more specifically an optical transmission line which can be used suitably in wavelength division multiplexing (WDM) optical communications.

[0002]

[Prior Art]

As the optical transmission technique advances in terms of an increase in speed and capacity, the WDM transmission technique is attracting much attention as the mainstream technique. However, as the power of optical signal is enhanced, a new problem has started to occur, that is, a non-linear phenomenon which takes place due to the interaction between optical signals of two or more waves within an optical path.

[0003]

Of the non-linear phenomenon, the four wave mixing (FWM) is considered to entail such a drawback that noise which occurs in the WDM transmission causes a serious adverse effect on the transmission, and therefore how to suppress it is being intensively studied. For example, OFC'94 Technical Digest PD19 proposes a dispersion shift optical fiber (DSF) which shifts the wavelength band to non-zero dispersion, as means for suppressing the non-linear phenomenon. More specifically, such a DSF that has non-zero dispersion at a 1.55 μm-wavelength band is used. In this case, the absolute value of the non-zero dispersion (unit: ps/nm/km) is, in many cases, set to 0.5 to 5.

[0004]

Further, the distortion of a waveform caused by self phase modulation (SPM) and cross phase modulation (XPM) is another very serious problem. In the studies on how to

solve such a problem, a research of suppressing the non-linear refraction index (n_2) reported in OFC'97 TuN1b or the like, is studied, and further attention is paid to the technique for enlarging the mode field diameter (MFD) of the DSF, that is, the technique for enlarging the effective core area (A_{eff}) of the core.

[0005]

The distortion ϕ_{NL} of a signal, which is caused by the non-linear phenomenon is expressed generally by the following formula (1):

$$\phi_{NL} = (2\pi \times n_2 \times L_{eff} \times P)/(\lambda \times A_{eff}) \quad \ldots(1)$$

From the formula (1), it is understood that A_{eff} should be large to be advantageous. Further, A_{eff} is expressed by the following formula (2):

$$A_{eff} = k \times (MFD)^2 \quad \ldots(2)$$

where k is a constant.

From the formula (2), when MFD is large, a low non-linearity can be obtained very efficiently. As reported in OFC'96 WK15 and OFC'97 TuN2, the enlargement of MFD is presently one of the most required characteristics for the DSF.

[0006]

Besides the non-linear phenomenon, the distortion of waveform due to dispersion is another problem in terms of the transmission characteristics of optical fiber. For the suppression of the distortion of the waveform due to the dispersion while suppressing the non-linear phenomenon, the

method for managing the dispersion over the total optical line is effective. For example, in Jpn. Pat. Appln. KOKAI Publication No. 6-11620 proposes an optical transmission line achieved by combining a single-mode optical fiber (SMF) having zero dispersion at about 1.3 μm and a dispersion compensation optical fiber (DCF). Further, recently, an optical transmission line achieved by combining an SMF and a cable-type DCF is proposed as disclosed in, for example, Jpn. Pat. Appln. KOKAI Publication No. 10-325913.

[0007]

[Object of the Invention]

In general, a DSF having zero dispersion or micro-dispersion at a 1.55 μm-wavelength band has a high non-linearity and is easily influenced by XPM or SPM. As in the conventional case, a great number of researches have been made to reduce the non-linearity by enlargement of the MFD of the DSF; however the enlargement of the MFD of the DSF generally entails bending loss or an increase in dispersion slope. In the case of a DSF having non-zero dispersion at a 1.55 μm-wavelength band, although its use at a wavelength band for zero dispersion is avoided, the wavelength dispersion per unit length (local dispersion) is small, and therefore the FWM easily occurs as compared to the case of SMF.

[0008]

On the other hand, the SMF has a larger positive local dispersion (about 16 ps/nm/km at a 1.55 μm-wavelength band)

than that of a DSF having non-zero dispersion at a 1.55 μm-wavelength band, and therefore the FWM can be easily avoided. Further, since A_{eff} is relatively large (about 80 μm^2), a non-linear phenomenon such as XPM or SPM does not easily occur. Here, the deterioration of a signal waveform occurs due to large dispersion at a 1.55 μm-wavelength band; however it can be solved by managing the total line with use of a dispersion compensation optical fiber such as described above. Further, in general, an SMF has a low loss and low polarization mode dispersion value (PMD). That is, it can be said that an SMF is a relatively suitable fiber for the WDM transmission.

[0009]

However, as the speed and capacity of data transmission is further increased in the future, very high power is input to a fiber and therefore even a present SMF might have a problem of non-linear phenomenon. Further, a dispersion compensation optical fiber for compensating dispersion of SMF has a high non-linearity due to its structure, and therefore a non-linear phenomenon such as XPM or SPM easily occurs.

[0010]

[Means for Achieving the Object]

Thus, an object of the present invention is to provide a positive dispersion optical fiber of a new type, which solves the above-described problems, as a substitute for the conventional SMF, and an optical transmission line which

includes such a positive dispersion optical fiber in its part.

[0011]

A first solving means of the present invention provides an optical fiber which has a dispersion value at a set wavelength band in a 1.5 μm-wavelength band, of 14 to 24 ps/nm/km, and, an effective core area at a central wavelength of said set wavelength band is 95 μm^2 or more, and a bending loss at a bending diameter of 20 mm is 20 dB/m or less, and which operates in a single mode at said set wavelength band.

[0012]

A second solving means of the present invention provides an optical fiber which has a dispersion value at a set wavelength band in a 1.5 μm-wavelength band, of 6 to 14 ps/nm/km, and, an effective core area at a central wavelength of said set wavelength band is 70 μm^2 or more, and a bending loss at a bending diameter of 20 mm is 20 dB/m or less, and which operates in a single mode at said set wavelength band.

[0013]

A third solving means of the present invention provides an optical fiber according to any one of solving means 1 or 2, wherein a dispersion slope (unit: ps/nm^2/km) at said set wavelength band is 0.08 or less in absolute value.

[0014]

A fourth solving means of the present invention

provides an optical fiber according to any one of solving means 1 to 3, wherein a transmission loss at a central wavelength in said set wavelength band is 0.25 dB/km or less, and a polarization mode dispersion value is 0.15 ps/km$^{1/2}$ or less.

[0015]

A fifth solving means of the present invention provides an optical fiber according to solving means 4, wherein a transmission loss at an entire region of the set wavelength band is 0.25 dB/km or less.

[0016]

A sixth solving means of the present invention provides an optical fiber according to any one of solving means 1 to 5, which comprises a single layer core and clad, and has a refractive index profile of a single peaked structure, and which satisfies 0.2% $\leqq$ $\Delta 1$ $\leqq$ 0.35% where $\Delta 1$ is a relative refractive index difference of the core with reference to the refractive index of the clad.

[0017]

A seventh solving means of the present invention provides an optical fiber according to any one of solving means 1 to 5, which comprises a single layer core and clad, and has a refractive index profile of a single peaked structure, and which satisfies 0.2% $\leqq$ $\Delta 1$ $\leqq$ 0.6% where $\Delta 1$ is a relative refractive index difference of the core with reference to the refractive index of the clad, and satisfies 1 $\leqq$ α $\leqq$ 5 where α is a value obtained when the refractive

index profile is approximated with an α curve.

[0018]

An eighth solving means of the present invention provides an optical fiber according to any one of solving means 1 to 5, which comprises a center core, a side core and a clad in order from an inner side, and has a refractive index profile of a two-layer core type, and which satisfies $0.2\% \leqq \Delta 1 \leqq 0.35\%$ and $-0.3\% \leqq \Delta 2 < 0$ where $\Delta 1$ is a relative refractive index difference of the center core, with reference to the refractive index of the clad, and $\Delta 2$ is a relative refractive index difference of the side core, with reference to the refractive index of the clad, and satisfies $0.3 \leqq a/b \leqq 0.7$ where a represents an outer diameter of the center core and b represents an outer diameter of the side core.

[0019]

A ninth solving means of the present invention provides an optical fiber according to any one of solving means 1 to 5, which comprises a center core, a side core and a clad in order from an inner side, and has a refractive index profile of a two-layer core type, and which satisfies $0.2\% \leqq \Delta 1 \leqq 0.7\%$ and $-0.3\% \leqq \Delta 2 \leqq -0.15\%$ where $\Delta 1$ is a relative refractive index difference of the center core, with reference to the refractive index of the clad, and $\Delta 2$ is a relative refractive index difference of the side core, with reference to the refractive index of the clad, and satisfies $0.3 \leqq a/b \leqq 0.7$ where a represents an outer

diameter of the center core and b represents an outer diameter of the side core, and satisfies $1 \leqq \alpha \leqq 5$ where α is a value obtained when the refractive index distribution is approximated with an α curve.

[0020]

A tenth solving means of the present invention provides an optical fiber according to any one of solving means 1 to 5, which comprises a center core, a side core and a clad in order from an inner side, and has a refractive index profile of a two-layer core type, and which satisfies $0.2\% \leqq \Delta 1 \leqq 0.35\%$ and $0 < \Delta 2 < \Delta 1$ where $\Delta 1$ is a relative refractive index difference of the center core, with reference to the refractive index of the clad, and $\Delta 2$ is a relative refractive index difference of the side core, with reference to the refractive index of the clad, and satisfies $0.3 \leqq a/b \leqq 0.7$ where a represents an outer diameter of the center core and b represents an outer diameter of the side core.

[0021]

An eleventh solving means of the present invention provides an optical fiber according to any one of solving means 1 to 5, which comprises a center core, a side core and a clad in order from an inner side, and has a refractive index profile of a two-layer core type, which satisfies $0.2\% \leqq \Delta 1 \leqq 0.7\%$, $0.15\% \leqq \Delta 2 \leqq 0.3\%$ and $\Delta 1 > \Delta 2$ where $\Delta 1$ is a relative refractive index difference of the center core, with reference to the refractive index of the clad,

and $\Delta 2$ is a relative refractive index difference of the side core, with reference to the refractive index of the clad, and satisfies $0.3 \leqq a/b \leqq 0.7$ where a represents an outer diameter of the center core and b represents an outer diameter of the side core, and satisfies $1 \leqq \alpha \leqq 5$ where α is a value obtained when the refractive index profile is approximated with an α curve.

[0022]

A twelfth solving means of the present invention provides an optical fiber according to any one of solving means 1 to 5, which comprises a first core, a second core and a clad in order from an inner side, and has a refractive index profile of a two-layer core type, which satisfies $0.6\% \leqq \Delta 2 \leqq 1.0\%$ and $-1.2 \leqq \Delta 1/\Delta 2 \leqq -0.4$ where $\Delta 1$ is a relative refractive index difference of the first core, with reference to the refractive index of the clad, and where $\Delta 2$ is a relative refractive index difference of the second core, with reference to the refractive index of the clad, and satisfies $0.3 \leqq a/b \leqq 0.7$ where a represents an outer diameter of the first core and b represents an outer diameter of the second core.

[0023]

A thirteenth solving means of the present invention provides an optical fiber according to any one of solving means 1 to 5, which comprises a first core, a second core, a third core and a clad in order from an inner side, and has a refractive index profile of a three-layer core type, and

which satisfies $0.6\% \leqq \Delta 2 \leqq 1.0\%$, $-1.2 \leqq \Delta 1/\Delta 2 \leqq -0.4$ and $0.2 \leqq \Delta 3/\Delta 2 \leqq 0.6$ where $\Delta 1$ is a relative refractive index difference of the first core, with reference to the refractive index of the clad, $\Delta 2$ is a relative refractive index difference of the second core, with reference to the refractive index of the clad, and $\Delta 3$ is a relative refractive index difference of the third core, with reference to the refractive index of the clad, and satisfies $0.3 \leqq a/b \leqq 0.7$ and $0.2 \leqq a/c \leqq 0.5$ where a represents an outer diameter of the first core, b represents an outer diameter of the second core, and c represents an outer diameter of the third core.

[0024]

A fourteenth solving means of the present invention provides an optical transmission line for transmitting an optical signal, wherein the optical fiber according to any one of solving means 1 to 13, is arranged in the optical transmission line in its part.

[0025]

It should be noted here that in the present specification, unless it is specifically indicated, the 1.5 μm-wavelength band is meant to be a wavelength range of 1520 to 1620 nm, and the set wavelength band in the 1.5 μm-wavelength band is meant to be a wavelength band in the wavelength range of 1520 to 1620 nm, where signal is actually transmitted in an optical transmission line, which is, for example, a conventional 1.55 μm-wavelength band

(mostly wavelength range of 1530 to 1570). Further, the band of the set wavelength band is supposed to be a band of 30 nm or higher, in consideration of being used in the WDM transmission.

[0026]

The optical fiber of the present invention is a remodeled version of the conventional SMF, and the actual use form thereof is substantially the same as that of the conventional SMF. Here, the optical fiber of the present invention will now be described in consideration of the actual use form of the conventional SMF.

[0027]

The conventional SMF has a dispersion of about 16 ps/nm/km near a wavelength of 1.55 μm and has a dispersion slope of about 0.065 ps/nm^2/km. When transmission is carried out near a wavelength of 1.55 μm with use of the SMF, the distortion of the waveform occurs due to the dispersion. For this reason, an SMF is generally used in combination with an optical fiber for compensating dispersion of the SMF, which occurs near a wavelength of 1.55 μm, that is, for example, DCF. Therefore, in order to consider the transmission characteristics of the SMF near a wavelength of 1.55 μm, it is realistic to evaluate the total performance of the optical transmission line including the DCF.

[0028]

These dispersion compensation optical fibers can be

designed to have a negative dispersion and a negative dispersion slope by controlling the profile of its refractive index. Therefore, when these optical fibers are combined in respectively appropriate quantity, the dispersion of the optical transmission line as a whole can be adjusted to become approximately zero in a wide range of the 1.5 μm-wavelength band. In this manner, where performing the WDM transmission at the 1.5 μm-wavelength band, it becomes possible to suppress the deterioration of the signal waveform, which is caused by the dispersion.

[0029]

Further, even if the dispersion of the optical transmission line as a whole is substantially zero, an SMF and DCF has a large local-dispersion, and therefore it is possible to suppress FWM as well, which is prominent in a non-zero small dispersion region. Therefore, the optical transmission line having a structure of combination of SMFs and DCFs is very suitable for high-speed and large capacity WDM transmission.

[0030]

However, even if the deterioration of the waveform, which is caused by the dispersion and FWM can be suppressed, when A_{eff} of the optical finer is small or the non-linear refractive index is large, the deterioration of the signal waveform due to the XPM or SPM easily occurs.

[0031]

These non-linear phenomena are prominent when the power

of light is high, and therefore such an order as shown in FIG. 6 is effective, that is, an optical fiber having a lower non-linearity is arranged after the optical amplifier in the path, and an optical fiber of a higher non-linearity than that of the one provided in the front stage is arranged at sections where the light has been weakened. For example, it is considered that the following arrangement order is preferable in order to suppress the deterioration of the waveform, caused by the non-linear phenomenon such as SPM or XPM. That is, an SMF having an A_{eff} value of 80 μm^2 or higher is arranged immediately after the optical amplifier, and a DCF having A_{eff} value of about 20 μm^2 is arranged in a later stage.

[0032]

Nevertheless, the non-linearity of the DCF is significantly large as compared to that of the SMF, and therefore for a large-capacity transmission, it is possible that the deterioration of the waveform occurs due to the non-linear phenomena within the DCF. Further, recently, there has been developed a dispersion compensation type optical fiber having a lower non-linearity, which is called RDF, as reported in ECOC'97 Vol. 1, page 127.

[0033]

However, with such an RDF, the non-linearity expressed by the formula (1) is one-order larger as compared to the case of the SMF and consequently, there is a possibility that the non-linear phenomenon cannot be neglected for the

case of large-capacity transmission.

[0034]

Under these circumstances, for example, if the length of the fiber in the preceding stage can be made longer, the fiber having a lower non-linearity can be made longer. Consequently, the light with a more attenuated power is made incident on the high non-linearity fiber situated on the later stage. In this manner, the non-linear phenomena of the fiber of the later stage can be suppressed.

[0035]

Further, the SMF itself, although it has an A_{eff} value of about 80 μm^2 and is of a low non-linearity type, is an optical fiber placed immediately after the optical amplifier. Therefore, it is considered that there will be a demand of further extension of the A_{eff} value, that is, reduction of the non-linearity, as the distance and capacity increase rapidly.

[0036]

Further, generally, SMFs and DCFs are matched together in terms of lengths thereof such that the dispersion in total becomes substantially zero, and therefore as the dispersion in an SMF becomes smaller, the length of the SMF becomes longer. The conventional SMF has a dispersion of about +16 ps/nm/km, and therefore if it is possible to make the dispersion about +16 ps/nm/km or less, the length of the SMF can be elongated. As a result, it becomes possible to control the power of signal made incident on a high

non-linear fiber located in a later stage.

[0037]

However, when the dispersion value comes excessively small, there is a possibility that the FWM phenomenon occurs. Thus, we consider that the dispersion value should preferably be near +6 to +14 ps/nm/km. Further, with regard to the non-linearity, if a level similar to the conventional one can be achieved, the non-linear phenomenon in an optical fiber in a later stage can be suppressed, and therefore it is considered that the non-linear phenomenon in total can be suppressed.

[0038]

Further, while maintaining the dispersion of the SMF at about the present level, if the A_{eff} value can be expanded further to 95 μm^2 or more (that is, expanding the A_{eff} value by about 10% or more as compared to the conventional type SMF), the non-linear phenomenon in the SMF in the preceding stage can be suppressed to a lower level than that of the conventional case. Therefore, the non-linear phenomenon can be suppressed in the optical transmission line as a whole.

[0039]

Preferably, the A_{eff} value of the SMF should be expanded and the dispersion value should be made smaller than that of the conventional SMF, for example, about +6 to +14 ps/nm/km. In this manner, the non-linear phenomena in both of the preceding and later stages can be suppressed, and therefore the non-linear phenomenon in the optical

transmission line as a whole is considered to become a very small value.

[0040]

Under these circumstances, a novel optical fiber having a low non-linearity, which is different from the conventional SMF, as well as a transmission line which uses such an optical fiber are proposed.

[0041]

However, if the dispersion slope is increased as compared to that of the conventional SMF, it becomes difficult to compensate the dispersion in a wide range despite that the dispersion compensation-type optical fiber is used. Therefore, it is preferable that the distribution of the refractive index should be set to note that the absolute value of the dispersion slope (unit: $ps/nm^2/km$) does not increase to become over 0.08.

[0042]

Further, when the bending loss increases, a serious problem such as an increase in loss after forming a cable, will be caused. Therefore, it is preferable that the distribution of the refractive index should be set to note that the bending loss at a bending diameter of 20 mm does not become 20 dB or more.

[0043]

Further, in the case where an optical fiber is used in a practical use condition, that is, for example, being formed into a cable, and thereby the cut-off wavelength

becomes larger than the minimum wavelength of the wavelengths utilized, that is, the minimum wavelength of the 1.5 μm-wavelength band, the single mode operation in the optical transmission line as whole cannot be guaranteed. In order to avoid this, it is desirable that the distribution of the refractive index should be set noting that the cut-off wavelength under at least a practical use condition should not become the minimum wavelength of the wavelengths used or more.

[0044]

[Embodiment of the Invention]

Various embodiments of the solving means will now be described with reference to accompanying drawings.

[0045]

FIG. 1 is an explanatory diagram showing the profile of the refractive indexes of an optical fiber according to the first embodiment of the present invention. The refractive index profile shown in FIG. 1 indicates the index of a core 11 and that of a clad 14 from the inner side in order. The core 11 has a maximum relative refractive index difference $\Delta 1$ with respect to the clad 14. Here, the diameter of the core 11 is a.

[0046]

It should be noted that the conventional SMF has a refractive index profile shown in FIG. 1. A structure in which $\Delta 1$ = about 0.4% and α = infinity, that is, a structure close to a step type is general.

[0047]

In view of the above, a simulation was carried out on the basis of the conventional SMF, and the result indicated that it was found that it would be possible to expand the A_{eff} value to 95 μm^2 by setting $\Delta 1$ in FIG. 1 in a range of $0.2\% \leqq \Delta 1 \leqq 0.35\%$, or setting it in a range of $0.2\% \leqq \Delta 1 \leqq 0.6\%$, together with setting α to 5 or less. It should be noted that the reason for setting $\Delta 1$ to 0.2% or higher is that the bending loss is increased if $\Delta 1$ is set to less than 0.2%, and the reason for setting the upper limitation to $\Delta 1$ is not only that the A_{eff} is not sufficiently expanded, but also the PMD is deteriorated if it exceeds the upper limit.

[0048]

Further, the optical fiber according to this embodiment was able to obtain, in terms of dispersion, properties as good as those of the conventional SMF. Table 1 below indicates results of the simulation with the conventional SMF, and Table 2 below indicates results of the simulation with an A_{eff} extension type positive distribution optical fiber according to this embodiment.

[0049]

[Table 1]

	$\Delta 1$	α	Core diameter a	Dispersion value	Dispersion slope	MFD	A_{eff}	λc
Unit	%		μm	ps/nm/km	ps/nm^2/km	μm	μm^2	nm
Sim1	0.40	∞	10.00	16.42	0.0597	10.0	79.4	1295

[0050]

[Table 2]

	$\Delta 1$	α	Core diameter b	Dispersion value	Dispersion slope	MFD	A_{eff}	λc
Unit	%		μm	ps/nm/km	$ps/nm^2/km$	μm	μm^2	nm
Sim2	0.35	14.0	10.75	16.88	0.0591	10.95	95.5	1435
Sim3	0.30	15.0	11.75	17.16	0.0609	11.65	107.6	1452
Sim4	0.25	14.0	14.50	18.13	0.0610	13.20	138.7	1512
Sim5	0.40	2.0	13.50	14.01	0.0603	10.98	96.8	1423

[0051]

As can be understood as described above, the A_{eff} value can be expanded by setting $\Delta 1$ in a range of $0.2\% \leqq \Delta 1 \leqq 0.35\%$. Further, in the case where $\Delta 1$ is set it in a range of $0.2\% \leqq \Delta 1 \leqq 0.6\%$, together with setting α in a range of $1 \leqq \alpha \leqq 5$, the dispersion can be reduced, and the length of the positive dispersion fiber with respect to the entire light transmission line is increased. Therefore, it was found in addition to the above that the effect of suppressing the non-linear phenomenon of the dispersion compensation type optical fiber would be expected.

[0052]

As described before, it is possible to achieve the lowering of the non-linearity with such a form that the core has a single layer structure; however there is a general trend that the bending loss increases. Therefore, with a structure in which a second-layer core, more specifically,

a side core, is provided around the above core, and the refractive index of the side core is made lower than that of the first core (to be referred to as "center core" hereinafter) so as to have some degree of difference as compared to the clad level, the bending loss can be easily suppressed and the A_{eff} can be easily expanded. Thus, although the structure becomes somewhat complicated, such a two-layer core structure can be employed.

[0053]

FIG. 2 is an explanatory diagram showing the profile of the refractive indexes of an optical fiber according to the second embodiment of the present invention. The refractive index profile shown in FIG. 2 indicates the refractive index of a center core 21, that of a side core 22 and that of a clad 24 from the inner side in order. The center core 21 has a maximum relative refractive index difference $\Delta 1$ with respect to the clad 24, and the side core 22 has a maximum relative refractive index difference $\Delta 2$ with respect to the clad 24. Here, the diameter of the center core 21 is a, and the diameter of the side core 22 is b. It should be noted that in FIG. 2, there is a relationship of $\Delta 1 > 0 > \Delta 2$.

[0054]

In the case of the optical fiber having such a refractive index profile as shown in FIG. 2, the effect of suppressing the bending loss becomes very low when $\Delta 2 > -0.15\%$, whereas the extension of the A_{eff} becomes insufficient when $\Delta 2 < -0.30\%$.

[0055]

FIG. 3 is an explanatory diagram showing the profile of the refractive indexes of an optical fiber according to the third embodiment of the present invention. The refractive index profile shown in FIG. 3 indicates the refractive index of a center core 31, that of a side core 32 and that of a clad 34 from the inner side in order. The center core 31 has a maximum relative refractive index difference $\Delta 1$ with respect to the clad 34, and the side core 32 has a maximum relative refractive index difference $\Delta 2$ with respect to the clad 34. Here, the diameter of the center core 31 is a, and the diameter of the side core 32 is b. It should be noted that in FIG. 3, there is a relationship of $\Delta 1 > \Delta 2 > 0$.

[0056]

In the case of the optical fiber having such a refractive index profile as shown in FIG. 3, the effect of suppressing the bending loss becomes very low and the dispersion slope increases when $\Delta 2 < 0.15\%$, whereas the extension of the A_{eff} becomes insufficient when $\Delta 2 > 0.30\%$.

[0057]

Further, as to an optical fiber having such a refractive index profile as shown in FIG. 2 or FIG. 3, it was found that a core diameter ratio a/b was measured under conditions that the dispersion value at a wavelength of 1.55 μm becomes 1.5 times or less than that of the conventional SMF and the absolute value of the dispersion

slope (unit: ps/nm^2/km) does not exceed 0.08, and a relationship of a/b ≧ 0.3 was obtained. Further, when a range in which the A_{eff} value is expandable more than that of the conventional SMF was measured, and a relationship of a/b ≦ 0.7 was obtained.

[0058]

Therefore, in the second and third embodiments of the present invention, it can be concluded that the absolute value of the relative refractive index difference Δ2 of the side core with regard to the clad should preferably be 0.15% ≦ |Δ2| ≦ 0.30%, and the ratio between the outer diameter a of the center core and the outer diameter b of the side core should preferably be 0.3 ≦ a/b ≦ 0.7. The ground for determining the range of the relative refractive index difference Δ1 of the center core with regard to the clad is essentially the same as that for determining the range of the relative refractive index difference Δ1 of the core 11 with regard to the clad in the first embodiment of the present invention.

[0059]

In the above-mentioned range, the simulation of SMF having a two-layer structure was carried out, and the following results were obtained. The results are shown in Table 3.

[0060]

[Table 3]

	Δ1	α	Δ2	a/b	Core diameter b	Dispersion value	Dispersion slope	MFD	A_{eff}	λc
Unit	%		%		μm	ps/nm/km	$ps/nm^2/km$	μm	$μm^2$	nm
Sim6	0.25	14.0	-0.15	0.50	35.00	19.73	0.0628	14.20	158.4	1528
Sim7	0.35	14.0	-0.25	0.50	18.50	17.94	0.0607	11.48	111.3	1436
Sim8	0.50	4.0	-0.25	0.55	15.00	12.99	0.0592	10.44	91.18	1387
Sim9	0.25	14.0	0.20	0.55	22.50	17.44	0.0619	13.27	159.2	1522
Sim10	0.30	16.0	0.20	0.45	16.50	15.41	0.0609	12.29	118.3	1460
Sim11	0.60	3.0	0.25	0.50	12.25	11.48	0.0611	10.89	90.07	1496

[0061]

As shown in Table 3 above, in either of the optical fibers, the A_{eff} value is expanded further than that of the conventional SMF (about 80 μm^2), and in two of them, the A_{eff} value exceeds 150 μm^2. Further, in connection with the two having small α values, the dispersion value is small. As the length of the positive dispersion optical fiber increases as compared to the DCF, the optical power input to the DCF can be suppressed and thus the non-linear phenomenon can be suppressed.

[0062]

FIG. 4 is an explanatory diagram showing the refractive index distribution of the optical fiber according to the fourth embodiment of the present invention. The refractive index profile shown in FIG. 4 shows the refractive indexes

of the first core 41, the second core 42 and the clad 44 in the order from the inner side. The first core 41 has a minimum relative refractive index difference $\Delta 1$ with respect to that of the clad 44, and the second core 42 has a maximum relative refractive index difference $\Delta 2$ with respect to that of the clad 44. The diameter of the first core 41 is represented by a, and the diameter of the second core 42 is represented by b. It should be noted that in FIG. 2, there is a relationship of $\Delta 1 < 0 < \Delta 2$.

[0063]

With regard to an optical fiber having a refractive index profile in which the center core has the refractive index profile of a depressed shape as shown in FIG. 4 was examined in terms of the possibility that it could be a low non-linear optical fiber. First, from the simulation, a profile capable of making the A_{eff} value 95 μm^2 or more was searched from a simulation.

[0064]

First, while fixing $\Delta 2$ at constant (in this case, 0.7%), the variation of the properties was examined in the case where $\Delta 1$ is changed. Here, the bending loss when the A_{eff} value was set to 95 μm^2 or more was examined, and it was found that the bending loss would be increased unless $\Delta 1$ is -0.2% or less.

[0065]

Under these circumstances, while fixing $\Delta 1$ at -0.2%, the value of $\Delta 2$ which could keep the bending loss at

a bending diameter of 20 mm, to be 20 dB/m or less was examined from a simulation, and it was found that it would require 0.6% or higher. It was further found that if Δ2 exceeds 1.0%, the A_{eff} value would become 95 μm^2 or less and the extension would be insufficient.

[0066]

Further, under the above-described conditions, a range for the core diameter ratio a/b which can make the bending loss low even if the A_{eff} value was 95 μm^2 or more was examined, and it was found that a range of $0.3 \leqq a/b \leqq 0.7$ would be preferable. Within this range, various simulations were conducted, and the optimal case was searched for. The results of the search were shown in Table 4 below.

[0067]

[Table 4]

	Δ1	Δ2	a/b	Core diameter b	Dispersion value	Dispersion slope	MFD	A_{eff}	λc
Unit	%	%		μm	ps/nm/km	ps/nm²/km	μm	μm²	nm
Sim12	-0.4	0.8	0.5	10.50	8.88	0.077	10.02	84.5	1535
Sim13	-0.5	0.8	0.5	11.00	7.16	0.078	9.65	76.6	1515
Sim14	-0.6	0.6	0.5	10.50	8.84	0.073	10.07	84.7	1508
Sim15	-0.6	0.7	0.5	10.00	7.40	0.073	9.14	72.8	1523

[0068]

As can be understood from Table 4 above, the A_{eff} can be expanded 70 μm^2 or more, that is, substantially the same level as that of the conventional SMF or even more.

[0069]

However, the optical fiber having such a refractive index profile as shown in FIG. 4 has a merit as compared to the conventional SMF; however as to the A_{eff} value, it is still at the same level as that of the conventional case. Therefore, in consideration of further extension of the A_{eff} value, a new refractive index profile was examined.

[0070]

FIG. 5 is an explanatory diagram showing the profile of the refractive indexes of an optical fiber according to the fifth embodiment of the present invention. The refractive index profile shown in FIG. 5 indicates the refractive index of a first core 51, that of a second core 52, that of a third core 53 and that of a clad 54 in the order from the inner side. The diameter of the first core 51 is a, that of the second core 52 is b, and that of the third core 53 is c. The first core 51 has a minimum relative refractive index difference $\Delta 1$ with respect to that of the clad 54, the second core 52 has a maximum relative refractive index difference $\Delta 2$ with respect to that of the clad 54, and the third core 54 has a maximum relative refractive index difference $\Delta 3$ with respect to that of the clad 54. It should be noted that in FIG. 5, there is a relationship of $\Delta 1 < 0 < \Delta 3 < \Delta 2$.

[0071]

In FIG. 5, when $\Delta 3$ is less than 0.1%, the effect of extending the A_{eff} value is low and when $\Delta 3$ exceeds 0.30%, the cut-off wavelength increases thus making impossible to

satisfy the single mode transmission conditions in the wavelength band of use. Under these circumstances, a case where Δ3 is fixed to 0.20% was examined. It should be noted that in this embodiment, Δ1, Δ2 and a core diameter ratio a/b were set as those of the fourth embodiment.

[0072]

Within the above range, a simulation was conducted with regard to the refractive index profile shown in FIG. 5, and the following results were obtained. The results are shown in Table 5 below.

[0073]

[Table 5]

	Δ1	Δ2	Δ3	a:b:c	Core diameter c	Dispersion value	Dispersion slope	MFD	A_{eff}	λc
Unit	%	%	%		μm	ps/nm/km	$ps/nm^2/km$	μm	μm^2	nm
Sim16	-0.4	0.6	0.20	1:2:4	10.00	14.51	0.066	10.64	99.4	1541
Sim17	-0.5	0.7	0.25	1:2:4	10.00	14.94	0.068	11.11	110.3	1536
Sim18	-0.5	0.6	0.30	1:2:3	10.00	13.08	0.069	11.28	114.8	1487

[0074]

In any one of the optical fibers, the A_{eff} value is expanded to about 100 μm^2, or even more. Further, the dispersion values are set relatively small. Therefore, it is considered that as the length of the positive dispersion optical fiber increases as compared to the DCF, the optical power input to the DCF can be suppressed and thus the non-linear phenomenon can be suppressed.

[0075]

The inventions, which are remodeled versions of the conventional SMF, have been described so far, and now an optical transmission line which employs the optical fiber of the present invention will now be described.

[0076]

FIG. 6 is an explanatory diagram of an optical transmission system according to the sixth embodiment of the present invention, including an optical transmission line which employs the optical fibers according to the first to fifth embodiments of the present invention. In FIG. 6, reference numeral 61 denotes an optical transmitter, numerals 62a and 62b denote optical amplifiers, 63a and 63b denote positive dispersion optical fibers, 64a and 64b denote negative dispersion optical fibers such as DCF and the like, and 65 denotes an optical receiver. The structure itself of the system shown in FIG. 6 is equivalent to the conventional system; however when the optical fibers of the present invention are used for a part thereof, more specifically, 63a, 63b and the like, the transmission property can be significantly improved.

[0077]

That is, by applying the optical fibers of the present invention to the optical transmission system shown in FIG. 6, a low non-linearity (that is, FWM, SPM, XPM and the like are suppressed), a flatness of the dispersion slope, and a low bending loss property as an entire optical transmission line

can be achieved. These properties of the low non-linearity, the flatness of the dispersion slope, and the low bending loss property of a novel optical transmission line which employs novel optical fibers are optimal for an optical transmission line. Thus, it has become possible to easily manufacture a link suitable for high-speed and large-capacity data transmission.

[0078]

(Embodiment 1)

The effectiveness of the present invention will now be confirmed by way of the following embodiments. First, employing such a single peak structure as shown in FIG. 1, samples of optical fibers were prepared on the basis of the results of the simulation shown in Table 1 above. The results of the samples are shown in Table 6 below. In Table 1, properties except cut-off wavelength λc are values at a wavelength of 1550 nm. Sample cases 1, 2, and 3 in Table 6 correspond respectively to Sim 3, Sim 2, and Sim 5 in Table 2.

[0079]

[Table 6]

	Trans-mission loss	Dispersion	Dispersion slope	MFD	A_{eff}	Bending loss	λc
Unit	dB/km	ps/nm/km	$ps/nm^2/km$	μm	$μm^2$	dB/km	nm
Trial example 1	0.185	17.3	0.057	11.74	110.2	9.7	1444
Trial example 2	0.190	16.1	0.058	10.91	95.6	7.2	1395
Trial example 3	0.200	13.2	0.059	10.89	95.1	5.3	1429

[0080]

The results shown in Table 6 above approximately resemble those of Table 1 above. That is, with regard to all of the sample cases, the A_{eff} value was 95 μm^2 or more and further, $\Delta 1$ was as small as that of the conventional SMF, and therefore it is expected that the distortion of the waveform due to the XPM and SPM can be suppressed. Further, the dispersion value at a 1.55 μm-wavelength band was sufficiently large approximately as the same level as that of the conventional SMF, and therefore it is expected that the signal noise due to the FWM can be suppressed. Furthermore, the loss and bending loss were suppressed to low values, and therefore it can be understood that they can be sufficiently of a practical use.

[0081]

In particular, such a type as that of the sample case 3 has a small dispersion value, and therefore the length of the DCF used as it is connected to each optical fiber of the present invention can be shortened, and therefore it is expected mainly that the non-linearity in the DCF can be relatively suppressed.

[0082]

(Embodiment 2)

Further, more samples were prepared on the basis of the results of the simulations, shown in Tables 2 and 3 above. The results of the samples are shown in Table 7 below. In Table 7, properties except cut-off wavelength λc are values

at a wavelength of 1550 nm. Sample cases 4 to 9 correspond respectively to Sim 6 to 11 in Table 3 in order.

[0083]

[Table 7]

	Trans-mission loss	Dispersion	Dispersion slope	MFD	A_{eff}	Bending loss	λc
Unit	dB/km	ps/nm/km	ps/nm^2/km	μm	μm^2	dB/km	nm
Trial example 4	0.190	19.1	0.061	14.38	161.8	4.9	1470
Trial example 5	0.200	17.9	0.059	10.89	99.2	2.7	1394
Trial example 6	0.205	12.1	0.058	10.11	89.6	1.2	1395
Trial example 7	0.195	17.8	0.062	13.77	150.9	5.0	1436
Trial example 8	0.205	15.4	0.059	10.95	98.0	3.5	1465
Trial example 9	0.210	11.2	0.058	10.79	90.6	1.3	1449

[0084]

The results shown in Table 7 above approximately resemble those of Tables 2 and 3 above. That is, with regard to all of the sample cases, the A_{eff} value was extended, and therefore it is expected that the distortion of the waveform due to the SPM and XPM can be suppressed. Further, although the profile becomes somewhat complicated as compared to the case of the optical fiber shown in FIG. 1, even if the A_{eff} value was extended, the bending loss was suppressed to a small level.

[0085]

In particular, such types as those of the sample cases 6 and 9, the dispersion value was suppressed to a small value, and therefore a new effect of becoming able to

suppress the non-linearity of a fiber in a later stage can be expected.

[0086]

(Embodiment 3)

Further, more samples were prepared on the basis of the results of the simulations, shown in Tables 4 and 5 above. The results of the samples are shown in Table 8 below. In Table 8, properties except cut-off wavelength λc are values at a wavelength of 1550 nm. Sample cases 10 and 11 correspond respectively to Sim 12 and 14 in Table 4, and sample cases 12 and 13 correspond respectively to Sim 18 and 17 in Table 5.

[0087]

[Table 8]

	Trans-mission loss	Dispersion	Dispersion slope	MFD	A_{eff}	Bending loss	λc
Unit	dB/km	ps/nm/km	ps/nm^2/km	µm	µm^2	dB/km	nm
Trial example 10	0.210	8.1	0.071	10.08	89.8	3.9	1470
Trial example 11	0.205	7.9	0.072	9.84	80.2	3.7	1394

[0088]

The results shown in Table 8 above approximately resemble those of Tables 4 and 5 above. That is, since the optical fibers shown in FIGS. 4 and 5 each have a depressed distribution portion at the central portion, the refractive index distribution becomes somewhat complicated; however the A_{eff} value was extended and the absolute value of the

dispersion was made small, and therefore it is considered that as an entire optical transmission line, a significant suppression of the non-linear phenomenon can be achieved. Further, the transmission loss and bending loss can be suppressed to low levels as compared to those of the conventional case.

[0089]

As described above, the positive dispersion fiber of the present invention has excellent properties in the low non-linearity, low loss and bending loss. In the case where WDM transmission is attempted at a 1.5 μm-wavelength band, the dispersion and dispersion slope will act as obstacles. However, a low dispersion can be achieved in a wide wavelength range by connecting a dispersion compensation optical fiber or a dispersion slope compensation optical fiber or the like thereto. Therefore, it is considered that such a problem should be solved in the future with great possibilities.

[0090]

Further, the optical fiber of the present invention has a small dispersion as compared to that of the conventional SMF, and therefore it is understood that the length of the dispersion compensation optical fiber used as being connected to the optical fiber of the present invention can be shortened, and thus a further low non-linearity can be achieved as an entire optical transmission line. Further, with regard to the core 1 shown in FIG. 1 and the center

core 1 in each of FIGS. 2 and 3, the relative refractive index difference is set substantially lower that that of the conventional SMF, and therefore the PMD in any of the fibers exhibited a low value as 0.1 ps/km$^{1/2}$ or less.

[0091]

[Advantage of the Invention]

According to the present invention, it is possible to establish a low non-linear positive dispersion fiber suitable for high-speed and large-capacity data transmission and having a further lower non-linearity than that of the conventional SMF, a low transmission loss, low bending loss and a low PMD, as well as an optical transmission line which employs such an optical fiber.

[Detailed Description of the Drawings]

[FIG. 1]

A diagram showing an example of the profile of the refractive index of an optical fiber according to the first embodiment of the present invention.

[FIG. 2]

A diagram showing an example of the profile of the refractive index of an optical fiber according to the second embodiment of the present invention.

[FIG. 3]

A diagram showing an example of the profile of the refractive index of an optical fiber according to the third embodiment of the present invention.

[FIG. 4]

A diagram showing an example of the profile of the refractive index of an optical fiber according to the fourth embodiment of the present invention.

[FIG. 5]

A diagram showing an example of the profile of the refractive index of an optical fiber according to the fifth embodiment of the present invention;

[FIG. 6]

A diagram showing a transmission system according to the sixth embodiment of the present invention including an optical fiber according to the first to fifth embodiment of the present invention.

[Explanation of Reference Symbols]

11 … Core,

14, 24, 34, 44, 54 … Clad,

21, 31 … Center core,

22, 32 … Side core,

41, 51 … First core,

42, 52 … Second core,

53 … Third core,

61 … Optical transmitter,

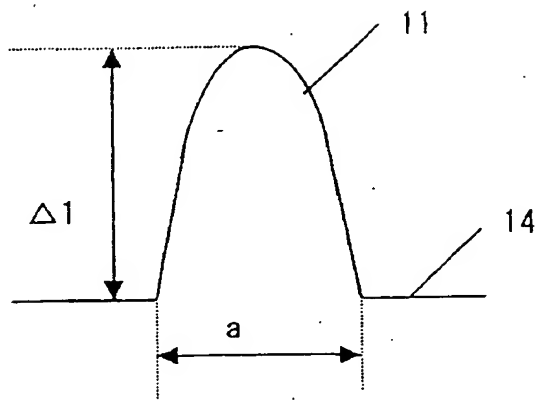
62 … Optical amplifier,

63a, 63b … SMF,

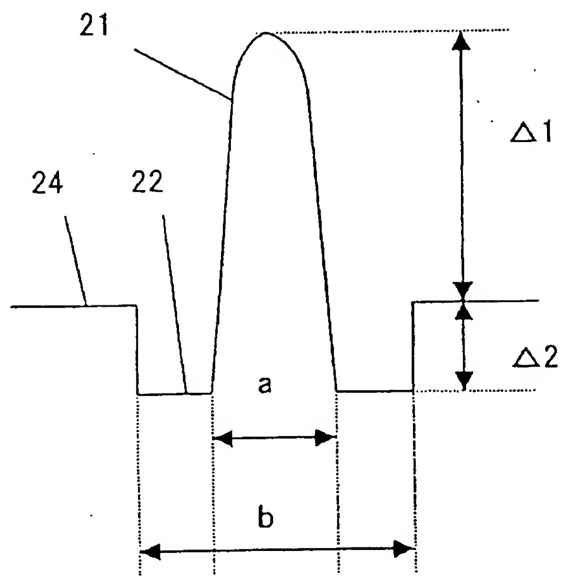
64a, 64b … L-RDF,

65 … Optical receiver.

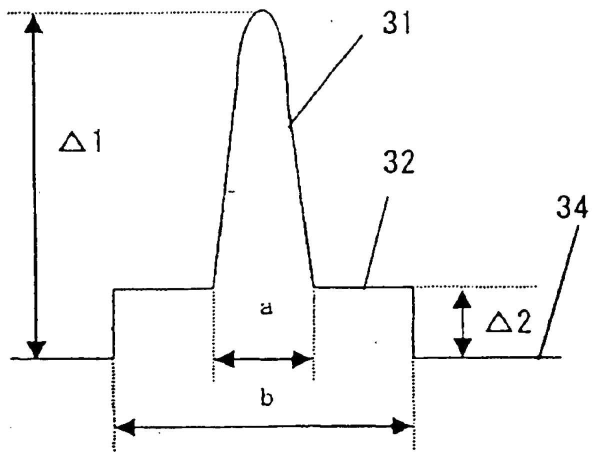
【書類名】　図面
[NAME OF DOCUMENTS]　DRAWINGS
【図１】
[FIG. 1]



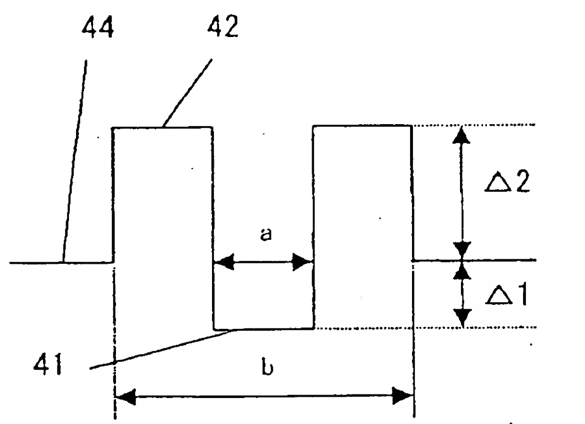
【図２】
[FIG. 2]



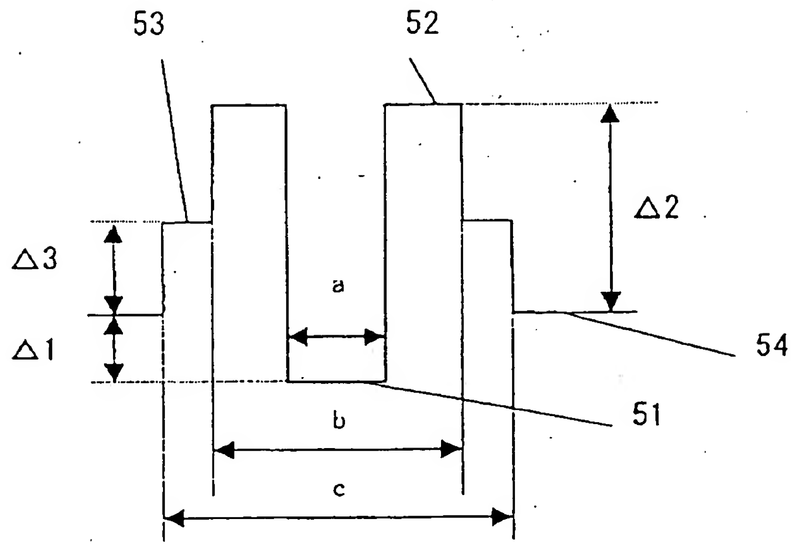
【図３】
[FIG. 3]



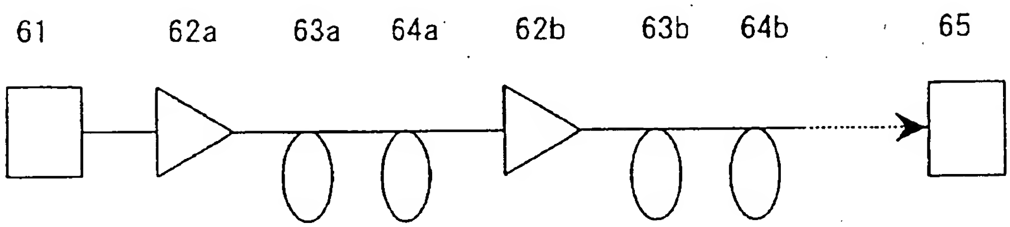
【図４】
[FIG. 4]



【図５】
[FIG. 5]



【図６】
[FIG. 6]



[Document] ABSTRACT

[Abstract]

[Object] Since an optical power increases in optical transmittance, it is necessary to employ a novel optical fiber having a further lower non-linearity than that of the conventional SMF.

[Means for Achieving the Object] There is provided an optical fiber which has a dispersion value at a set wavelength band in a 1.5 μm-wavelength band, of 14 to 24 ps/nm/km, and, an effective core area at a central wavelength of said set wavelength band is 95 μm^2 or more, and a bending loss at a bending diameter of 20 mm is 20 dB/m or less, and which operates in a single mode at said set wavelength band.

[Elected Figure] FIG. 1

APPLICANT'S PAST DATA

Identification Number	[000005290]
1. Date of Change	August 29, 1990
[Reason for Change]	New Registration
Address:	6-1, Marunouchi 2-chome, Chiyoda-ku, Tokyo
Name:	The Frukawa Electric Co., Ltd